USER GUIDE FOR DISTAL RADIUS FRACTURE CLASSIFIER

A Convolutional Neural Network Model for Image Classification

Abstract

This classifier takes the standard three x-ray views of the wrist taken for a suspected distal radius fracture, PA view, oblique view, and lateral view, in DICOM format and classifies the fracture as Type I, Type II, or Type III according the Orbay-Mercer system.

A. Laurie Wells

AnLWells@salud.unm.edu

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A. Laurie Wells, PhD

Research Program Specialist

Department of Orthopaedics and Rehabilitation

University of New Mexico School of Medicine

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Preface

The work for this classifier was done in partial fulfillment of a Master of Science degree in Data Science at Grand Canyon University. All the data used for training and validation of the convolutional neural network (CNN) was obtained from the University of New Mexico (UNM) Health Sciences Center (HSC) picture archiving and communication system (PACS).

Table of Contents

General Information

Orthopaedic surgeons at the University of New Mexico Health Sciences Center (UNM HSC) have developed a new classification system for distal radius fractures based on the stability of the distal radio-ulnar joint (DRUJ). This is clinically significant because instability of the DRUJ means that the wrist may need to be immobilized and early rotation of the affected arm will not be possible. A convolutional neural network (CNN) machine learning model was built to use plain x-rays of three views of the fracture to classify the fracture. The three views are posterior-anterior (PA) view, oblique view, and lateral view. The model was trained and validated using 300 cases from the UNM HSC PACS. An additional 50 cases were used to test the system. The most successful model parameters were saved and a classifier was built using Python.

The classification system is described below.

Type I: The triangular fibrocartilage complex (TFCC) and the distal portion of the interosseous forearm ligament or distal interosseous ligament (DIOL) remain intact after the distal radius fracture (DRF). There is no residual instability or subluxation of the distal radio-ulnar joint (DRUJ) after anatomical reduction of the skeletal structures. This is the injury found in minimally displaced DRF's and in fractures of both radius and ulna which occur just proximal to the DIOL. They need no specific treatment besides restoration of the bony anatomy.

Type II: The TFCC and the extensor carpi ulnaris (ECU) tendon sheath rupture but the DIOL remains intact. DRUJ subluxation is corrected and adequate stability is restored after anatomical reduction of the skeletal structures. The distal ulna and/or the ulnar styloid may or may not be fractured. This is the concomitant DRUJ injury found in most displaced DRF's.

Type III: The TFCC, the ECU tendon sheath and the DIOL all rupture. Therefore, all ligamentous support for the DRUJ is lost. After anatomical reduction of the skeletal structures, either subluxation of the DRUJ persists or clinical testing shows DRUJ instability. It is necessary to address the persisting DRUJ instability by specific means and early forearm rotation is usually not possible. This is the concomitant DRUJ injury found in the Galeazzi fracture, fractures of the distal radius with radio-ulnar diastasis and some high energy comminuted distal radius and ulna fractures (Mercer et al., 2021).

Table 1. Classification System

Intact/Not Intact +/-	TFCC/ECU	DIOL
Type I	+	+
Type II	–	+
Type III	–	–

System Summary

The basis of the classifier is a Python script file that runs in Python 3.8. The Spyder environment is suggested. When the script is executed, the user is prompted to enter information about the images that will be analyzed. The final window displays the classification of the fracture and x-ray images of a typical fracture of that type above the images for the classified fracture. The output of the classifier (softmax) for each type of fracture is also displayed. The user can use these numbers to gauge how certain the classification is.

Getting Started

The classifier is a stand-alone application. It is not intended to run in a cloud environment due to the potential to expose protected health information (PHI). All of the required files should be downloaded from the Google drive and placed in a common folder. Classifier is the suggested title. Table 2 lists the required files. A zip file with all the components can be downloaded here: https://drive.google.com/file/d/1zoe4OC38EIjxfC0WZsb_nhKgNcCe3AjQ/view?usp=sharing. Download the zip file and extract it locally.

You will need to have Python 3.8 installed on your computer along with the packages Pandas, NumPy, matplotlib, PySimpleGUI, keras, and pydicom. The classifier runs well in the Spyder environment as part of Anaconda.

Table 2. Files to run classifier

File	Description
DRUJClassifier.py	A Python script file that runs the classifier
model.json	A file containing the model parameters
model.h5	A file containing the model weights
TestCases	A folder containing 5 test cases with 3 images in DICOM format each
TypeI.png	An image file with a typical type I fracture
TypeII.png	An image file with a typical type II fracture
TypeIII.png	An image file with a typical type III fracture

Using the System

Running the Python script DRUJClassifier.py causes several interactive windows to open sequentially. The first window asks for a path for the needed files. Figure 1 is a screen shot of the first interactive window.

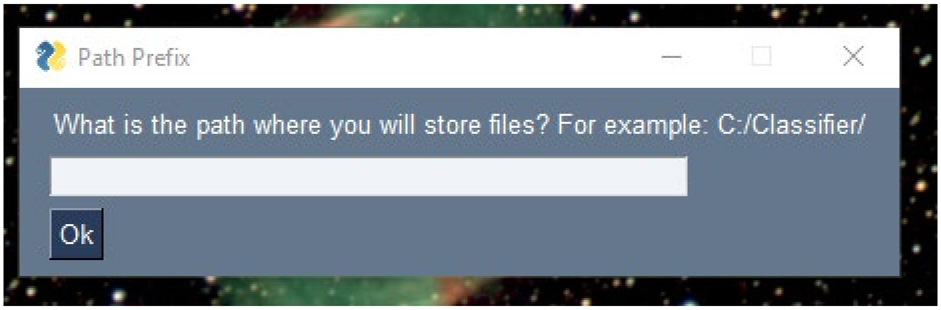

Figure 1. Window asking for path to classifier files.

The second window asks whether the images are for a left hand or a right hand. The classifier works best if the images are oriented in the same way, so right hands are reflected so that the radius is on the right of the image. All of the test cases included with the classifier are left hands. The window will accept both lower-case and upper-case, i.e. L or l and R or r. Figure 2 is a screen shot of the second interactive window.

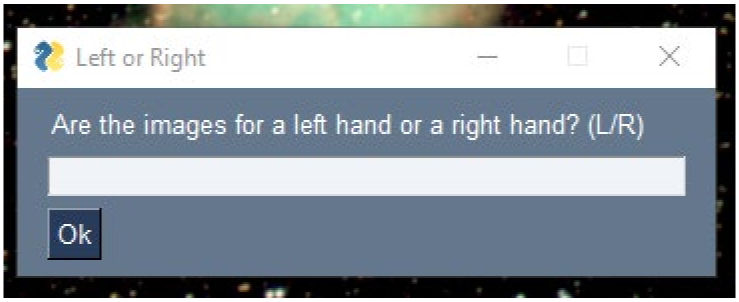

Figure 2. Window for asking for handedness of images.

The third through fifth windows ask for the files with the test case images. The user can “browse” to find the files. The test case images are labelled with the view. To classify your own images, you will need to know which files correspond to which views. Figure 3 show the third window and the dialog box generated by the “browse” button.

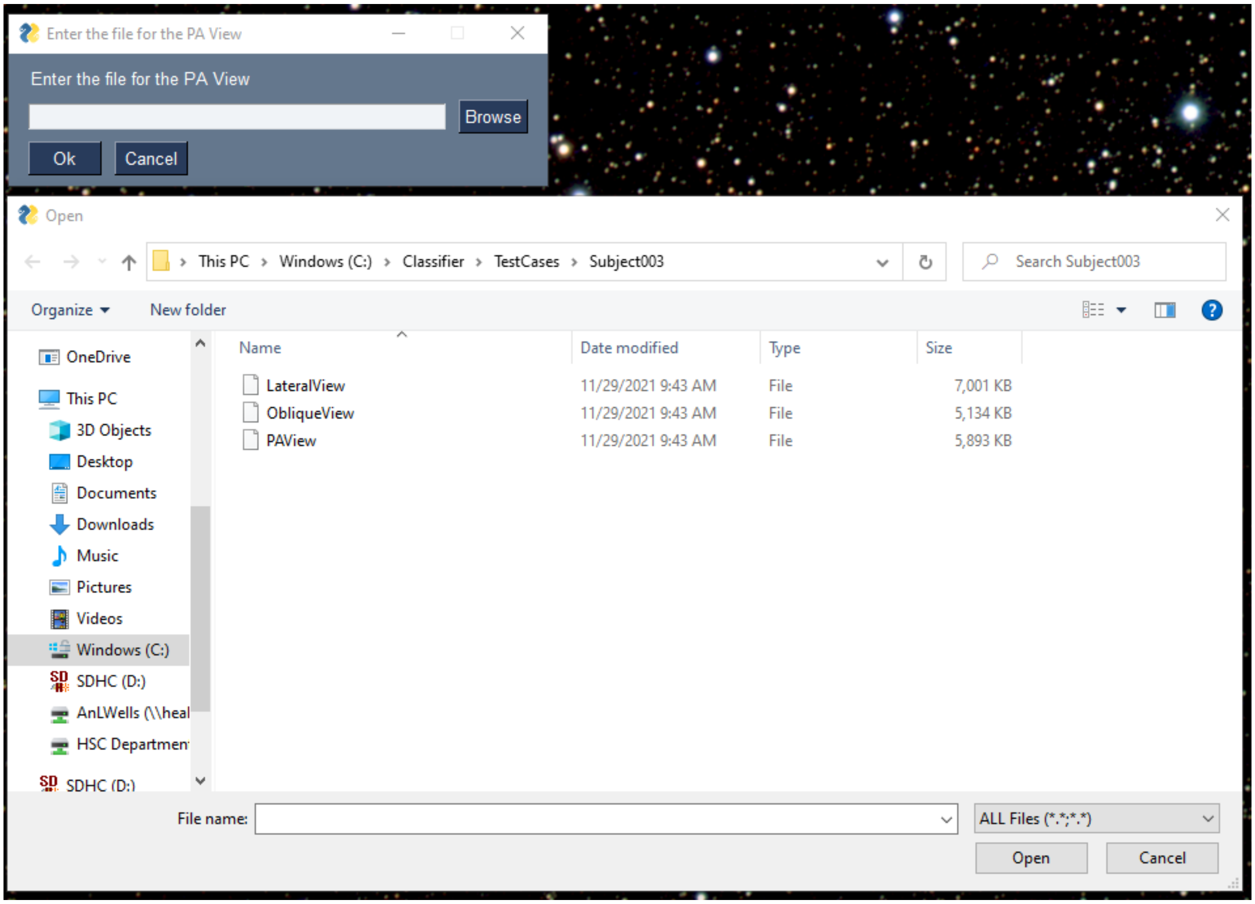

Figure 3. Window for file request and dialog box for selecting file.

The next set of windows are for cropping the images. The model was trained with images that were 1000 x 700 pixels. The first window for an image asks for the “crop height.” The pixels are numbered from (0, 0) in the upper left corner. If the fracture is fairly well centered in the view, enter 0.5. If the fracture is in the top half of the view, choose a number between 0 and 0.5. If the fracture is in the lower half of the view, choose a number between 0.5 and 1.0. Error messages are not currently implemented. If the user fails to enter a number between 0 and 1 in the dialog box, the program will freeze. This will be fixed in future implementations. The second window for an image asks for a “crop width.” Again, if the fracture is fairly well centered in the view, enter 0.5. If the fracture is closer to the left edge, enter a number between 0 and 0.5. If the fracture is closer to the right edge, enter a number between 0.5 and 1.0. Figure 4 shows the Crop Height window for the PA View.

Figure 4. Cropping window – Make sure to enter a number between 0 and 1 in the dialog box!

The final window displays the output from the model. It gives the classification of the fracture. It shows the softmax numbers for each type of fracture so that the user can estimate the reliability of the classification. Finally, a typical fracture of the type predicted is shown above the combined view of the classified fracture. Figure 5 shows the Model Output window.

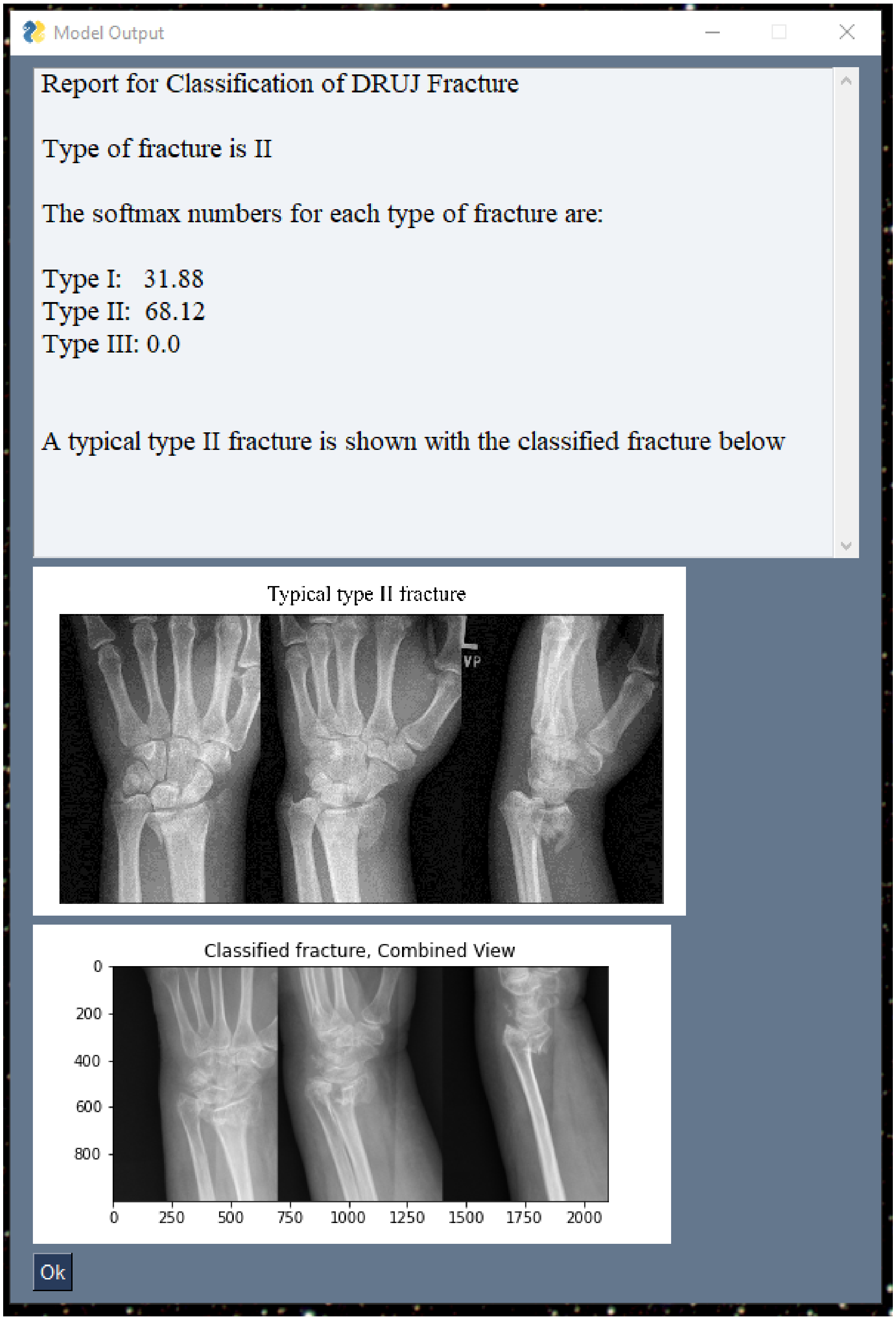

Figure 5. Model Output window

Troubleshooting

The interactive windows do not have error handling capability. That will be fixed in a future release. Currently, the program may freeze if an entry is left blank. At that point, you should end the program and start over. We are sorry for any aggravation caused by this.

Frequently Asked Questions (FAQ)

- What do the classifications mean?
    - The classification given by the program is the best estimate of the classification of the fracture obtained by putting a combined view of the three required images through the model. As always, final treatment decisions are the responsibility of the treating surgeon.
- Where can I get more information on convolutional neural networks?
    - A good description of convolutional neural networks can be found here: https://towardsdatascience.com/a-comprehensive-guide-to-convolutional-neural-networks-the-eli5-way-3bd2b1164a53

I expect to have more FAQs once some of the residents have worked with the program.

Help and Contact Details

If you have questions or problems with the classifier, contact Laurie Wells at AnLWells@salud.unm.edu.

This classification system for distal radius fractures is still in the experimental stage. If you are interested in participating in a multi-center study to further validate the system and the classifier, please contact Laurie Wells at AnLWells@salud.unm.edu.

Glossary

A good diagram of the wrist with the components described below, can be found here: https://handsurgeonsnyc.com/patient-education/wrist-anatomy/

DIOL – Distal interosseous ligament, the interosseous ligament is a membrane connecting the ulna and radius that runs the length of the forearm. The distal portion provides stability to the DRUJ

Distal – In anatomy, situated away from the body, the end of a bone in an arm or a leg farthest from the attachment to the body

DRUJ – Distal radio-ulnar joint, the joint where the long bones of the forearm meet the smaller bones of the wrist

ECU – Extensor carpi ulnaris, a construct that provides stability to the wrist

Radius – one of the bones of the forearm running from the elbow to the wrist

TFCC – Triangular fibrocartilage complex, a load bearing structure in the wrist connecting the ulna with some of the smaller bones

Ulna – one of the bones of the forearm running from the elbow to the wrist

References

Mercer, D., Heifner, J., Orbay, J., & Wells, A. L. (2021). Unpublished research protocol.